International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 2, Apr 2018, 391-396

TRANS STELLAR • Journal Publications • Research Consultancy

OPTIMIZATION OF TOOL WEAR FOR TURNING OPERATION BASED RESPONSE SURFACE METHODOLOGY

SAAD HAMEED AL-SHAFAIE

Department of Metallurgical Engineering, College of Materials Engineering, Babylon University, Babylon, Iraq

ABSTRACT

Present dissertation work has attempted to optimize the various significant cutting conditions for turning process by Response Surface Methodology (RSM). The dependent variable was tool wear (VB_{max}). The stainless steel AISI 316 SS has been used as a workpiece material, cutting speed (V), feed rate (f) and depth of cut (d) were selected as cutting conditions for this study. A face center composite design was selected for design of experiments. The results obtained from the experimental runs were analyzed using Minitab16 software. The corresponding values of the response parameter were also calculated using mathematical formulae and confirmed by performing validation experimentation. From the present experimental study, it is observed that $VB_{max.}$ in turning process is mainly affected by the depth of cut parameter as linear and square and interactions of cutting conditions ($V \times f$), ($V \times d$) all have a considerable impact on the VB_{max}. But, the depth of cut as linear has a major impact on the VB_{max}.

KEYWORDS: Tool Wear, Turning, Stainless Steel 316 & Response Surface Methodology

Received: Jan 31, 2018; **Accepted:** Feb 20, 2018; **Published:** Mar 05, 2018; **Paper Id.:** IJMPERDAPR201844

Original Article

INTRODUCTION

The flank wear is usually symbolized by ($VB_{max.}$), it is a large and influential part on the tool life and quality of product in cutting operation. It is one of the important tool wear forms in operations and has a negative influence on the productivity and dimensional accuracy. In practice, the tool life is assessed by the size of the VB. If it rises rapidly, the tool life turns into extremely shortened. In surface finish, tool life is decided by the cutting time of the same tool till the VB reaches certain criterion. Tool wear is a vital technical process factor of domination in the cutting operation. It is the surroundings for the assessment of the surface quality and tool life [1, 2]. Thus, improvement of a dependable VB advancement model will be very worth.

Considerable attempts have been performed by many investigators in modeling and understanding the VB advancement, wear mechanisms, quality of surface and tool life in machining. In the last years, a great concentration has been signed in the improvement of models in the machining. Kramer [3] improved a model to predict the VB of tools in elevation speed when cutting the steel. The chemical dissolution and the abrasive wear were predominant mechanisms. The authors (Singh and Rao) [4] improved a model to predict the ceramic tool wear in hard operation. $VB_{max.}$ was modeled on the basis of diffusion, adhesion and abrasion wear as predominant mechanisms. However, the rise in the normal force with the advancement in VB did not take into account in the model. It is extensively stated that cutting force effect additional with the advancement in VB. Singh and Vajpayee [5] improved a model to predict the VB take into account that abrasion wear as the major mechanisms. Yallese et al. [6] were explaining that surface finish when machining 100Cr6 steel.

Compared to other methods, the RSM is considered very attractive in newly years [7, 8]. Neseli et al. [9] utilized RSM to find out the influence of tool geometry factors on the surface finish of AISI 1040 with P25 insert. Yallese et al. [6 were detected that machining X200Cr12 by CBN using 120 m/min as a cutting speed is an optimal value. Çaydaş [10] investigate the effects of the cutting conditions (V, *f* and d), cutting tool type, and hardness of workpiece on surface finish, maximum interface temperature of the chip and tool, and flank wear during turning of 4340 steels. Dureja et al [11] utilized the RSM to examine the influence of cutting factors on VB and surface finish through turning of H11 steel using ceramic insert and they concluded that the VB is affected mainly by the hardness of workpiece, depth of cut and feed rate. Banga and Abrão [12] discovered when turning 100Cr6, that cutting speed is the greatest significant factor influencing tool life. Horng et al [13] was built a model to assess the Hadfield steel's machine's ability by RSM method. The authors have shown that the VB is affected by the cutting speed while the combined influence of the corner radius of the tool with the nose radius and the feed rate have significance on got surface finish.

The influence of cutting parameters (V, *f* and d) on flank wear (VB) has been investigated in the present study through the turning of stainless steel (AISI 316 SS) with high speed steel (HSS) tools using RSM to optimize the response.

EXPERIMENTAL SET UP

The experimentation was carried out on a lathe machine type (Harrison / England) with 2.2 KW as a power, feed rate of (0.03-1 mm/rev) and spindle speed of (40 - 2500 rpm). Stainless steel AISI 316 SS material was used as a workpiece, the chemical composite listed in Table 1. The HSS of ISO geometry 'CNMG 120366' was used throughout the experiment. $VB_{max.}$ is measured by an optical microscope (Visual Gage 250).

Table 1: Chemical Composition of AISI 316 SS

Elements	C	Mn	Si	P	S	Cr	Mo	Ni	N
Weight %	0.08	2.00	0.75	0.045	0.03	18.00	3.00	14.00	0.10

Selection of the Cutting Conditions and Their Levels

The cutting conditions and their levels given in Table 2 were selected based on an extensive literature survey and the range limitation of lathe machine.

Table 2: Cutting Condition and Their Levels

Factors	Unit	Levels		
Cutting speed (V)	m/min.	60	80	100
Feed rate (*f*)	mm/rev.	0.10	0.14	0.18
Depth of cut (d)	mm	0.30	0.6	0.9

Selection of the Array

The three variable levels were selected based on an extensive literature survey and the range limitation of lathe machine. Three cutting conditions at three levels controlled an entire of 16 experimental given in Table 3.

Table 3: Design of Experiments Based on RSM

Exp. No.	V m/min.	*f* mm/rev.	d mm
1	80	0.18	0.60
2	80	0.14	0.60
3	100	0.18	0.90

Table 3: Contd.,

4	100	0.10	0.90
5	80	0.14	0.30
6	100	0.18	0.30
7	80	0.14	0.90
8	100	0.14	0.60
9	80	0.14	0.60
10	100	0.10	0.30
11	60	0.18	0.30
12	60	0.10	0.30
13	60	0.18	0.90
14	60	0.10	0.90
15	60	0.14	0.60
16	80	0.10	0.60

RESULTS AND DISCUSSIONS

The experimental results for flank wear (VB) by varying the selected cutting conditions as per L16 RSM based on Center Composite Design (CCD). All observations worked out using MINITAB 16 software are tabulated in Table 4.

Table 4: Experimental Results for Flank Wear

Exp. No.	V (m/min.)	*f* (mm/rev.)	d (mm)	VB(µm)
1	80	0.18	0.60	84
2	80	0.14	0.60	68.5
3	100	0.18	0.90	125
4	100	0.10	0.90	95
5	80	0.14	0.30	62
6	100	0.18	0.30	86
7	80	0.14	0.90	88
8	100	0.14	0.60	85
9	80	0.14	0.60	68.5
10	100	0.10	0.30	68
11	60	0.18	0.30	56
12	60	0.10	0.30	45
13	60	0.18	0.90	75
14	60	0.10	0.90	62
15	60	0.14	0.60	55
16	80	0.10	0.60	60

ANOVA for VB

The objective of this table 5 was to analyze the impact of input parameters or cutting conditions on the $VB_{max.}$.

It can be obviously seen from the table 5, that the depth of cut (*d*), square (d^2), and interactions ($V\times f$, $V\times d$) all have a vital influence on the $VB_{max.}$. But, the depth of cut has a major influence on the VB_{max}.

Table 5: Analysis of Variance for VB

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Remark
Regression	9	5673.66	5673.66	630.406	102.84	0.000	Significant
Linear	3	5315.60	134.56	44.852	7.32	0.020	Significant
V	1	2755.60	0.12	0.125	0.02	0.891	Not Significant
f	1	921.60	19.38	19.378	3.16	0.126	Not Significant
d	1	1638.40	83.92	83.923	13.69	0.010	Significant
Square	3	149.06	149.06	49.686	8.11	0.016	Significant
V*V	1	42.50	0.01	0.007	0.00	0.974	Not Significant

Table 5: Contd.,							
f*f	1	39.27	11.10	11.098	1.81	0.227	Not Significant
d*d	1	67.28	67.28	67.280	10.98	0.016	Significant
Interaction	3	209.00	209.00	69.667	11.37	0.007	Significant
V*f	1	72.00	72.00	72.000	11.75	0.014	Significant
V*d	1	112.50	112.50	112.500	18.35	0.005	Significant
f*d	1	24.50	24.50	24.500	4.00	0.093	Not Significant
Residual Error	6	36.78	36.78	6.130			
Lack-of-Fit	5	36.78	36.78	7.356			
Pure Error	1	0.00	0.00	0.000			
Total	**15**	**5710.44**					

Regression Equation for VB

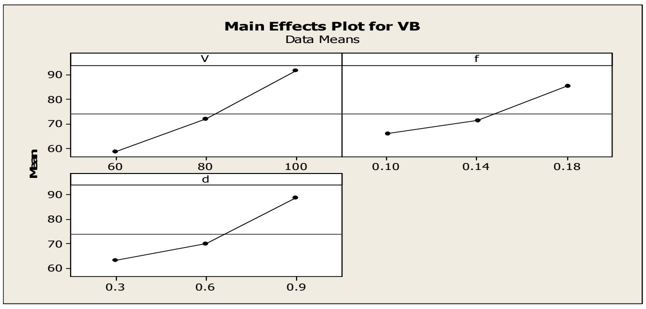
The relationship between the inputs (i.e., the cutting conditions) as an independent variable and the outputs (i.e., *VB*) as dependent variable were explained land linked with the coefficient of determinationR^2which shows the regression accuracy. The model which is produced from the analysis can be utilized to predict the VB and is dependent on the studied parameters

The models are offered in (Eq.1) to $VB_{max.}$

$$VB_{max.} = 40.7 - 0.07\,V - 60\,f - 87.77\,d + 67.037\,d^2 + 3.75\,V\,f + 0.625\,V\,d \quad (1)$$

Main Effect Plots of VB_{max}

The depth of cut has a very large impact on VB_{max} as shown in Figure 1. Feed rate and cutting speed have also a great influence. For the depth of cut, effect value is maximum and it has maximum levels of interaction. However, little depth of cut should be utilized to decrease the tendency to chatter. Thus, if the system of the tool - workpiece is not very rigid, the very little depth of cut should be utilized to avert the chatter. The figure shows main effects of tool flank wear and are plotted.



CONCLUSIONS

- The RSM is an efficient technique in deciding the optimum cutting conditions at a speed of 60 m/min, feed rate of 0.1mm/rev and depth of cut of 0.3mm to achieve a low $VB_{max.}$ of 45 µm.
- The important factor for $VB_{max.}$ is depth of cut. The feed rate and cutting speed have a slight effect on the full variation.
- The relationship between independent and dependent parameters is a multiple regression equation that can be utilized to evaluate the assessed values of the performance level for any parameter levels.

REFERENCES

1. *B. Fnides, M. A. Yallese, H. Aouici, Comportement à l'usure des céramiques de coupe (Al2 O3 + TiC et Al2 O3+ SiC) en tournage des pièces trempées. Algerian J. Advanced Materials 5 (2008) 121–124.*
2. *V. C. Uvaraja, N. Natarajan, Optimization on friction and wear process parameters using Taguchi technique. Int. J. Engineering Technology 2 (2012) 694–699*
3. *B. M. Kramer, A comprehensive tool wear model. CIRP Ann35 (1986) 67 – 70*
4. *D. Singh, P. V. Rao, Flank wears prediction of ceramic tools in hard turning. Int J Advanced Manufacture Technology 50 (2010) 479 – 493*
5. *Naveen Kumar Nayak et al., , Optimization of Cnc Turning Parameters for Al-6061 Using Response Surface Methodology, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) , Volume 7, Issue 4, July - August 2017, pp. 127-138*
6. *C. K. Singh, S. Vajpayee, Evaluation of flank wear on cutting tools. Wear 62 (1980) 247 – 254.*
7. *M. A. Yallese, K. Chaoui, N. Zeghib, L. Boulanouar, J. F. Rigal, Hard machining of hardened bearing steel using cubic boron nitride tool. J. Materials Processing Technology 209 (2009) 1092–1104*
8. *Garcia-Diaz, G. L. Hogg, F. G. Tari, Combining simulation and optimization to solve the multi-machine interference problem. Simulation 28 (1981) 193 – 201*
9. *D. E. Smith, An empirical investigation of optimum-seeking in the computer simulation situation. Oper Res 19 (1973)362 – 371*
10. *S. Neseli, S. Yaldiz, E. Türkes, Optimization of tool geometry parameters for turning operations based on the response surface methodology. Measurement 44 (2011)580-587*
11. *U. Çaydas, Machinability evaluation in hard turning of AISI 4340 steel with different cutting tools using statistical techniques, J. Engineering Manufacture 224 (2009)1034-1455*
12. *J. S. Dureja, V. K. Gupat, V. S. Sharma, M. Dogra, Design optimization of cutting conditions and analysis of their effect on tool wear and surface roughness during hard turning of AISI-H11 steel with a coated-mixed ceramic tool. J. Engineering Manufacture 223 (2009) 1441-1450*
13. *G. V. Benga, A. M. Abrao, Turning of hardened 100Cr6 bearing steel with ceramic and PCBN cutting tools. J. Materials Processing Technology 143(144) (2003) 237-241*
14. *J. T. Horng, N. M. Liu, K. T. Chiang, Investigation the machinability evaluation of had field steel in the hard turning with Al2O3/TiC mixed ceramics tool based on the response surface methodology. J. Materials Processing Technology 208 (2008) 532-541.*